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Nutrient and Heavy Metal Concentration and Distribution in Corn, Sunflower, and Turnip Cultivated in a Soil under Wastewater Irrigation

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Abstract

To study the potential uptake and accumulation of some essential elements and cadmium, a field experiment was conducted using three plants (sunflower, turnip, and forage corn in a randomized complete block design (RCBD) with three replications in a soil classified as Typic Haplogypsids under wastewater irrigation. The experiment site was selected in the farmfields located in Varamin region in southern Tehran, Iran (2005). The results showed that maximum concentrations of nitrogen, phosphorus, zinc, copper, and cadmium in sunflower were 6.05%, 1.27%, 97.27, 22.84 and 0.54 mgkg^{-1} respectively. The highest accumulation of nitrogen, phosphorus, zinc, and copper occurred in grain and cadmium in sunflower leaves. The maximum concentration of potassium and nitrate occurred in turnip leaves, while the maximum concentrations of iron and manganese were recorded in the root and leaves of forage corn, respectively.

Keywords: **cadmium; forage corn; macro and micronutrients; sunflower; turnip; wastewater**

I. Introduction

Nutrient availability changes continuously due to application of macro-, micronutrients and other trace elements through fertilizers, biosolids, irrigation wastewater or through indirect sources (i.e., car exhausts, rainfall and atmospheric deposition from several sources, etc.). Soils, as filters of toxic chemicals, may adsorb and retain heavy metals from wastewater. However, when the capacity of soils to retain toxic metals is reduced due to continuous loading of pollutants or changes in pH, soils can release heavy metals into groundwater or soil solution available for plant uptake. The effects of irrigation with wastewater on some micro nutrients and heavy metals in calcareous soil in southern Mosul, Iraq showed that the concentration of Fe, Zn, Mn and Cu as micro nutrients and Pb, Ni and Cd as heavy metals increased (Meani *et al* .,1993). Decomposition can also release heavy metals into soil solution. However, because of their low solubility and limited uptake by plants, heavy metals tend to accumulate in surface soil and become part of the soil matrix (McGrath *et al*., 1994). Through repeated wastewater applications, heavy metals can accumulate in soil to toxic concentrations for plant growth (Chang *et al*.,1992).

The long-term effects of irrigation with wastewater southern Tehran, Iran showed that the available concentration of OC, P, K, Zn, Cu, Cd, Pb and Ni were more than control soils (Molahoseini, 2001); therefore, in this area without significant decreased of wheat and forage corn yield, can reduce the amount of nitrogen, phosphorus and potassium to less than 75 percent of recommended soil test (Molahoseini, 2003a, 2005b).

The results of heavy metal contents of crops in the south of Tehran, Iran showed that the maximum accumulative concentration of these metals occurs in the following order: leaf, tuber, root, stem, fruit, and seed. The greatest uptake was found in turnip, lettuce, radish (leaf), sugar beet (leaf) and spinach, while the least was in rice and wheat (grain) and beetroot (Shariati *et al*., 1998).

Phytoremediation is one of the environment-friendly technologies that use plants to clean up soil from heavy metals and trace element contamination. The uptake and accumulation of pollutants vary from plant to plant , and from species to species within a genus (Singh *et al*., 2003). Another agronomic principle, which has been neglected in phytoremediation research, is crop rotation.

Because of the proliferation of weeds, predators, and diseases, which can cause significant yield reduction, crops

including those used for soil remediation, have to be rotated. In general, crops are rotated less frequently today than 30 years ago. From crop science, it can be extrapolated that short-term (two to three years) monoculture (the use of the same species in consecutive seasons), may be acceptable for metal phytoremediation.

However, for longer-term applications, as most metal phytoextraction projects are anticipated. It is unlikely that successful metal cleanup can be achieved with only one remediative species used exclusively in monoculture. Plant rotation is even more important when multiple crops per year are projected (Lasat *et al*., 2000).

In general terms, the macronutrient and micronutrient concentrations for the three crops were lower than those showed by Plank *et al*.(1995) .The normal range of nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were reported in the range of 3-5,o.3-o.5,3-5 percentage and 100-200,50-100,50-70,10-20 ppm in sunflower, 3-5.5,0.35-0.8,3-5 percentage and 80-370,30-100,20-70,3-10 ppm in turnip and 3-3.5,.25-0.45,2-2.5 percentage and 30-200,15-300,15-60,3-15 ppm in forage corn (Plank *et al*.,1995).

The normal range of cadmium (Cd) was 0.2-0.8 ppm in all the plants (Ross, 1996) and the normal range of nitrate (NO3) ion was less than 0.45 percentage(Maynard,1978).

The long-term effects of soils under irrigation wastewater in the south of Tehran, Iran cause to increase the available concentrations of OC, P, K, Zn, Cu, Cd, Pb and Ni more than control soils. This study was conducted to evaluate plant potential of sunflower, turnip, forage corn to uptake, and accumulate some essential elements and cadmium in soils under wastewater irrigation located in southern Tehran.

II. Materials and methodology

Site description and experimental design

This study was performed in a field experiment under wastewater irrigation in the south of Tehran, Iran. The soil was a Shahr-e-Rey Series, Typic Haplogypsids. The main characteristics of the topsoil (0-30 cm) were: 12.6 gr kg $^{-1}$ organic carbon; 0.13 gr kg $^{-1}$ average of total nitrogen; 72 mg kg $^{-1}$ average of available phosphorus by Olson method (Sparks *et al*., 1996); 287 mg kg -1 average of available potassium by flame photometry;21.6 mg kg $^{-1}$ average of available iron; 9.1 mg kg $^{-1}$ average of available manganese; 10 mg kg $^{-1}$ average of available zinc; 7.5 mg kg $^{-1}$ average of available copper; 37% clay; 49% silt; 14% sand and 7.5 pH. The average annual rainfall was 120 mm.

The three plant treatments; sunflower, turnip and forage corn were planted after wheat harvest during July to investigate the ability of the plants to accumulate some elements in different plant parts. The experimental design was a randomized complete block design (RCBD), with three replications during 2005-2006. Plot size was 30 square meters.

Plant sampling and analysis

Three plant samples per plot were taken in autumn, 2005. Each sample was a composite of two plants taken in the center of the plot. Then, each sample was separated into roots, and aboveground materials (stems, leaves, and grains) dried at 75 °C, weighed, grounded, homogenized and a representative sub sample, analyzed. For each sample, N was determined by Kjeldahl method; P was determined by spectrophotometry, and K was determined by flame photometry. Cadmium and trace elements (Cd, Cu, Fe, Mn and Zn) were extracted with DTPA (diethylen tetraamin penta acetic acid) and determined using atomic absorption. In all cases, the standard procedures described by Sparks *et al*. (1996) were used.

Statistical analysis

All the statistical analyses [ANOVA and Duncan test for comparison of the means] were done with SAS Software (version 9.1) to compare treatment effects on nutrients and cadmium content in plants tissues. Differences at $P > 0.05$ level were considered significant.

III. Results and discussion

Nutrient plant analysis

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Variance analysis of N, P, K, Fe, Mn, Zn, Cu and nitrate ion in grain, N, P, K, Fe elements and nitrate ion in leaf and root, N, P, K, Zn, Cu, and Mn and nitrate ion in stem of the plant treatments showed difference as compared to the control ($P< 0.01$). Cadmium was different in the plant treatments at $p< 0.05$ level. The nutrients and cadmium content of roots, leaf, stem, and grain of each crop are shown in Tables 1 and 2.

Macronutrient concentrations of crop tissues

The concentrations of the studied macronutrients N, P, K and NO3 showed some differences according to the plant treatment and their components. The maximum concentrations of N and P were measured in grain of sunflower where these values for K and NO3 occurred in turnip leaves (Table 1).

<INSERT TABLE 1 HERE>

According to Plank *et al*.(1995),the macronutrient concentrations of N, P and K for leaves of the three crops were lower than normal values. However, nitrate concentrations in turnip leaves was more than normal range by Maynard (1978) (normal range was 0.45 percentage).

Micronutrient concentrations of crop tissues

The concentrations and accumulation of the micronutrients and Cd also showed differences between the plant treatments (Table 2). The highest concentration of Fe and Mn were in forage corn root and leaves , respectively .The highest concentrations of Zn and Cu were in sunflower grain , and Cd was in sunflower leaves.

<INSERT TABLE 2 HERE>

According to Plank *et al*. (1995), the concentrations of Fe in forage corn and sunflower leaves were more than normal values, whereas Mn in forage corn was less than normal values and in sunflower and turnip leaves was close to the normal values. The determined data of Zn was lower than the normal range in leaves of the three plants, while the concentrations of Cu and Cd were more than the normal range in turnip leaves.

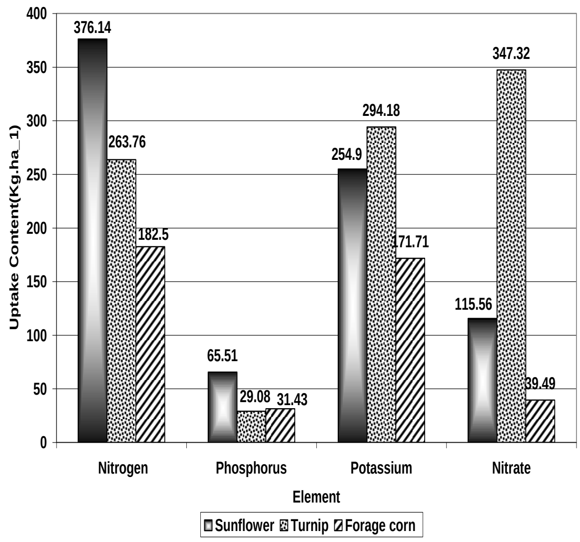

Figure 1. N, P, K, and nitrate ion uptake in sunflower, turnip and forage corn

Soil macro-, micronutrients, and crop cadmium uptake by crops

The highest uptake of N and P were 376.1 and 65.5 $Kg.ha^{-1}$ by sunflower and for K and nitrate ion were 294.2 and 347.3 $Kg.ha^{-1}$ by turnip , respectively. The highest uptakes of Fe, Cu, Zn and cadmium were 2.955, 0.643, 0.2, 0.003 $Kg.ha^{-1}$ by sunflower respectively and Mn was 0.537 $Kg.ha^{-1}$ by forage corn.

The results of this study showed that sunflower, turnip and forage corn have different potentials to concentrate and accumulate essential elements and cadmium from the soils under wastewater irrigation. Based on these results, the highest concentration and accumulation of N, P, Zn and Cu were in sunflower grain and cadmium in sunflower leaf. Moreover, the maximum concentration and accumulation of K and NO3 were in turnip leaf. Finally, the highest concentration and accumulation of Fe was in forage corn root, and Mn was in forage corn leaf. Therefore, proper plant rotation and suitable plant selection could decrease the accumulation of nutrients of the soil under wastewater irrigation.

Generally, in the soils under wastewater irrigation with excessive amount of essential elements and cadmium, it can be recommended to use sunflower to uptake excessive content of N, P, Zn, Cu and Cd; turnip to uptake excessive content of K and NO3; and forage corn for

uptaking excessive amounts of Fe and Mn without any yield decrease.

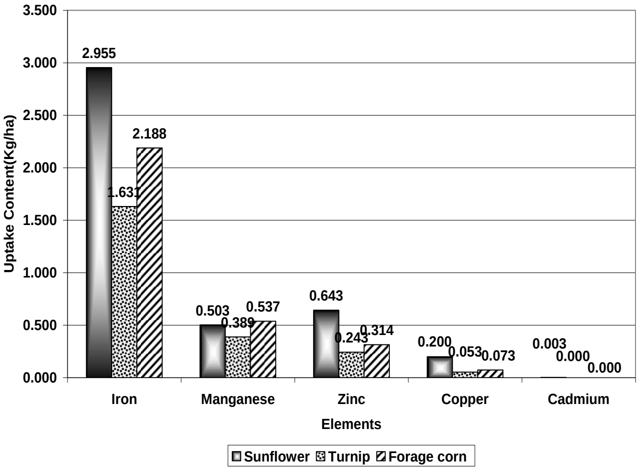

Figure 2. Fe, Mn, Zn, Cu, Cd elements uptake in sunflower, turnip and forage corn

IV. Conclusion

This study was conducted to evaluate the potentials of sunflower, turnip, forage corn to uptake and accumulate some essential elements and cadmium in the soils under wastewater irrigation located in southern Tehran, Iran. Based on the results, the lands under wastewater irrigation with excessive amounts of essential elements and cadmium may cultivate sunflower to uptake excessive contents of nitrogen, phosphorus, zinc, copper and cadmium, turnip to uptake excessive contents of potassium and nitrate, and forage corn to uptake excessive contents of iron and manganese without any yield decrease.

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Table 1: Macronutrient concentrations (%) in the plants and their components

Components	Crop	Nitrogen	Phosphorus	Potassium	Nitrate
	Sunflower	6.05a	1.27a	1.39a	0.00a
Grains	Turnip	0.00 c	0.00c	0.00c	0.00a
	Forage corn	2.57b	0.44 b	0.56b	0.00a
	Sunflower	3.46 b	0.35b	5.41a	0.50b
Leaves	Turnip	4.98 a	0.49a	5.79a	8.26a
	Forage corn	2.27c	0.25c	1.63b	0.05b
	Sunflower	0.98a	0.11a	1.19b	2.27a
Stems	Turnip	0.00 b	0.00b	0.00c	0.00b
	Forage corn	0.80a	0.18a	1.91a	0.49b
	Sunflower	0.49c	0.05c	1.92b	0.38b
Roots	Turnip	5.14a	0.61 a	5.56a	5.52a
	Forage corn	0.87b	0.12b	1.97b	1.29b

Means shown with different letters in each column have significant differences between the treatments at $P < 0.05$ in Duncan's test.

Table 2. Micronutrient and cadmium concentration(mg. kg^{-1}) in the plants components

Components	Crop	Iron	Manganese	Zinc	Copper	Cadmium
	Sunflower	86.45a	39.27a	97.27a	22.84a	0.28a
Grain	Turnip	0.00c	0.00c	0.00c	0.00c	0.00b
	Forage corn	27.45b	13.22b	29.44b	4.11b	0.06ab
	Sunflower	578.01a	107.27a	59.69a	20.49a	0.54a
Leaf	Turnip	278.22b	110.88a	42.11a	9.67a	0.00a
	Forage corn	349.56b	144.78a	54.89a	8.78a	0.00a
	Sunflower	32.51a	14.53b	18.12a	10.24a	0.06a
stem	Turnip	0.00a	0.00c	0.00b	0.00c	0.00a
	Forage corn	84.43a	39.78a	16.55a	5.98b	0.00a
	Sunflower	1025.11b	28.53b	24.37b	12.73a	0.00a
Root	Turnip	339.56c	48.22a	50.00a	10.55a	0.00a
	Forage corn	1341.0a	50.84a	33.83ab	12.42a	0.00a

Means shown with different letters in each column have significant differences between the treatments at $P < 0.05$ in Duncan's test.